Chemistry 151

- Professor James H. Geiger
- Office: Chemistry Building, Room 9
- Office Hours: **1:30-2:30 PM MWF,** and other times by appointment (send me an email).
- Email: geigerj@msu.edu
- Course website: Google "cem 151 MSU"
- Or go to D2L. The link is there. (https://www2.chemistry.msu.edu/courses/cem151/)

Textbooks/other help

- **Textbooks**
- **An on-line version comes with the on-line homework.**

  www.MasteringChemistry.com**.**

  If you want a hard copy version, I suggest you purchase any of the earlier editions: (Chemistry, the Central Science, 10th, 11th, 12th,13th,14th, etc. editions). You can find them on Amazon.

- **Lecture notes are available on the web.**

On line homework

- **Must be purchased**
- Will be required,
- is a big part of your grade!
- Make sure you do the introduction problem set, it is for credit as well.
- The same on line homework will be used in CEM 152.

Pearson

On line homework Signup:

To register for CEM 151 Fall 2024:

1. Go to https://mlm.pearson.com/enrollment/geiger65615
2. Sign in with your Pearson student account or create your account.
3. For Instructors creating a Student account, do not use your instructor credentials.
4. Select any available access option, if asked.
5. **»** Enter a prepaid access code that came with your textbook or from the bookstore. **»** Buy instant access using a credit card or PayPal. **»** Select **Get temporary access without payment**.
6. Select **Go to my course**.
7. Select **CEM 151 Fall 2024** from My Courses.

If you contact Pearson Support, give them the course ID: geiger65615 **To sign in later:**

1. Go to https://mlm.pearson.com
2. Sign in with the same Pearson account you used before.
3. Select **CEM 151 Fall 2024** from My Courses.

Mastering continued

- Access Customer Support at
- https://support.pearson.com/getsupport/s/contactsupport
- where you will find:
- - System Requirements
- - Answers to Frequently Asked Questions
- - Registration Tips & Tricks video
- - Additional contact information for Customer Support, including Live Chat

Course organization

- Lectures MWF 12:40-1:30 pm (me)

Recitation once a week (check your schedule). Small class, more individual help from Teaching assistants. Each section = 1 recitation group.

Grades

Course Grade

The final course grade is determined on an *absolute* (or flat) basis by the sum of the points obtained by the student on the homeworks, quizzes, the four tests, and the final examination.

Class attendance:	20 points extra credit
Homework:	175 points total
Recitation:	150 points total
Exams:	130 points each (520 total).
Final Exam:	145 points
Total:	1000 points.

NOTE: The 20 points of extra credit will require iClicker.

That will start NEXT WEEK.

How to succeed:

- Attend lecture and recitation
- Do homework problems!
- Do extra problems if you think you need them
- ***Being able to do the problems is key***
- Understand the concepts from lecture.

Lectures

- Will follow the book closely
- Example problems will be a key part.

Topics to be covered

First 9 chapters, Chapter 23 and 24 (15th ed.)

Chap 1 matter and measurement

- Chap 2, Atoms, molecules and Ions
- Chap 3 Stoichiometry, The Mole!
- Chap 4, reactions in water and solution stoichiometry
- Chap 5, Thermochemistry
- Chap 6, Electronic structure, atoms
- Chap 7, The periodic table
- Chap 8, Chemical bonding
- Chap 9, Molecular geometry
- Chap 23, Coordination chemistry
- Chap 24, Organic and biological chemistry

Chapter 1
Introduction:
Matter and Measurement

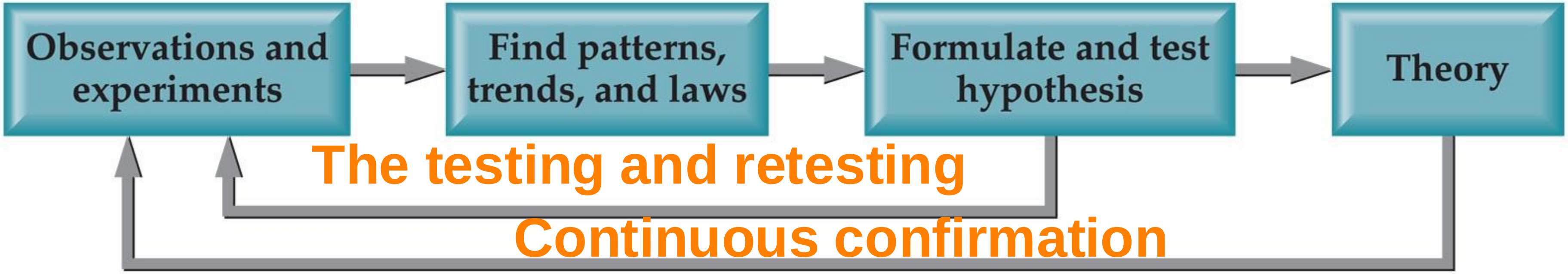
Scientific Method:

A systematic approach to solving problems.

Facts
Data

Empirical
relationships

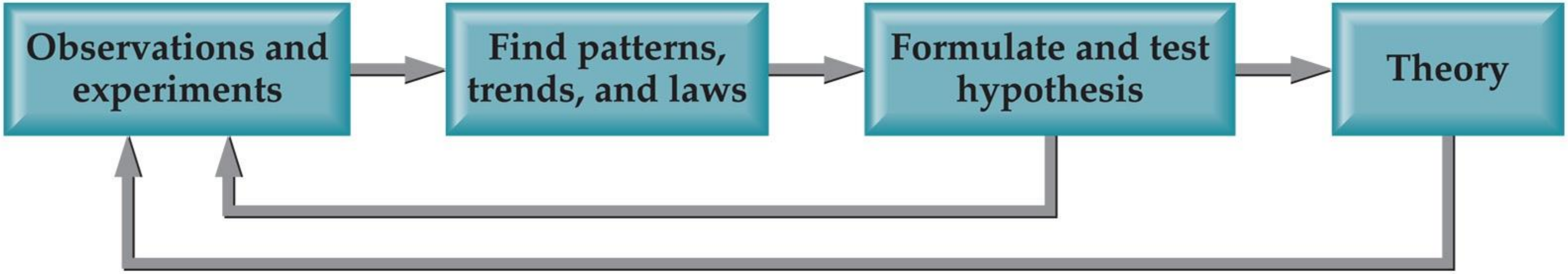
What is the
Underlying cause?
Make a model



This is what makes it Science!
The Theory *must* be consistent with *all* the data.
A single *conflicting* experiment can bring down a whole theory

Scientific Method:

A systematic approach to solving problems.



First devotee and developer:

Alhazen (1000 AD), Iraqi (Persian?), optics.

Chemistry:

The study of matter

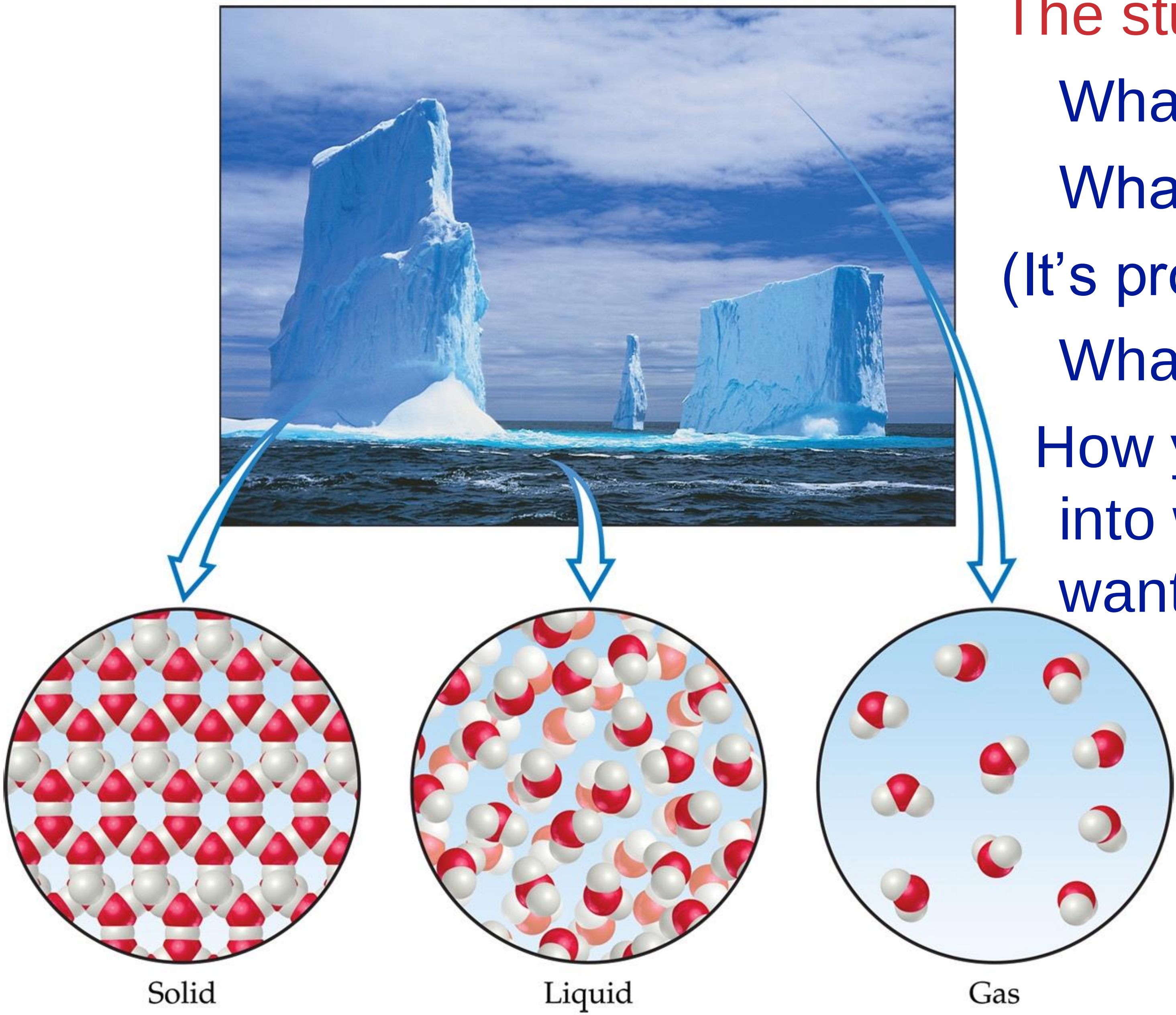
What it **is**

What it's like

(It's properties)

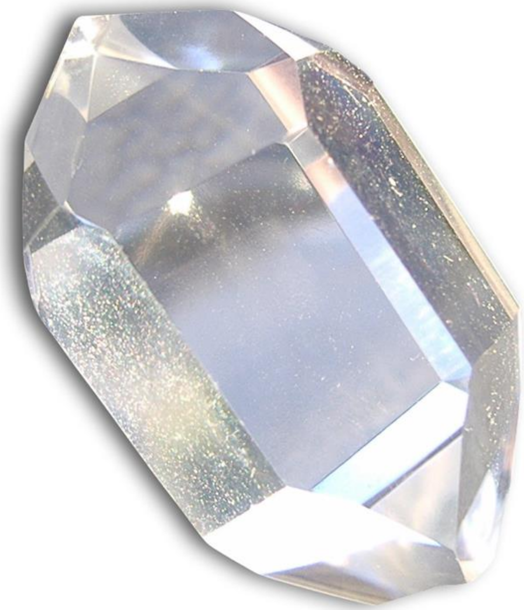
What it *becomes*

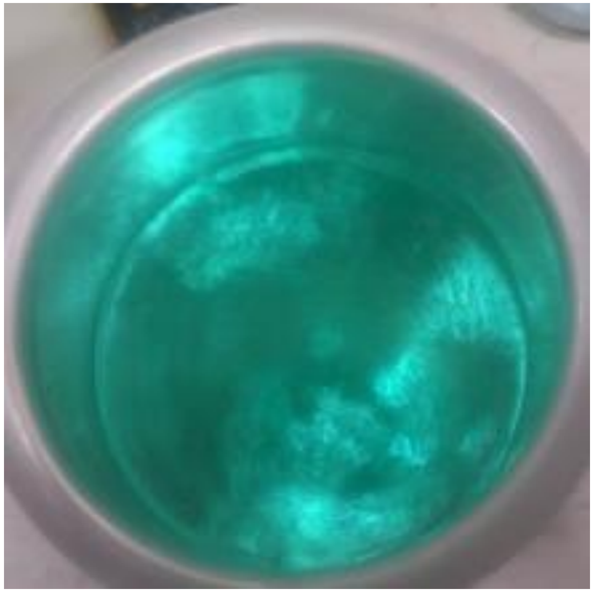
How you **make** it into what you want it to be



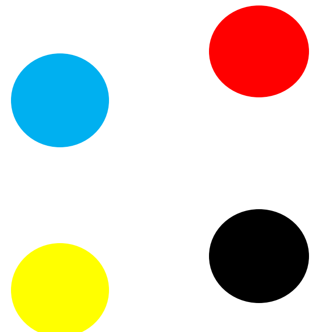
Matter:

Anything that has mass and takes up space. STUFF.





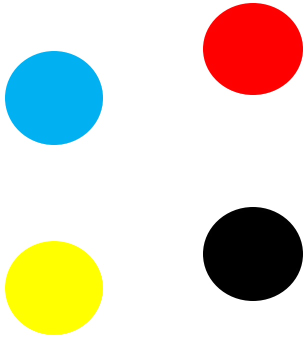
Matter



- **Atoms** are the building blocks of matter.

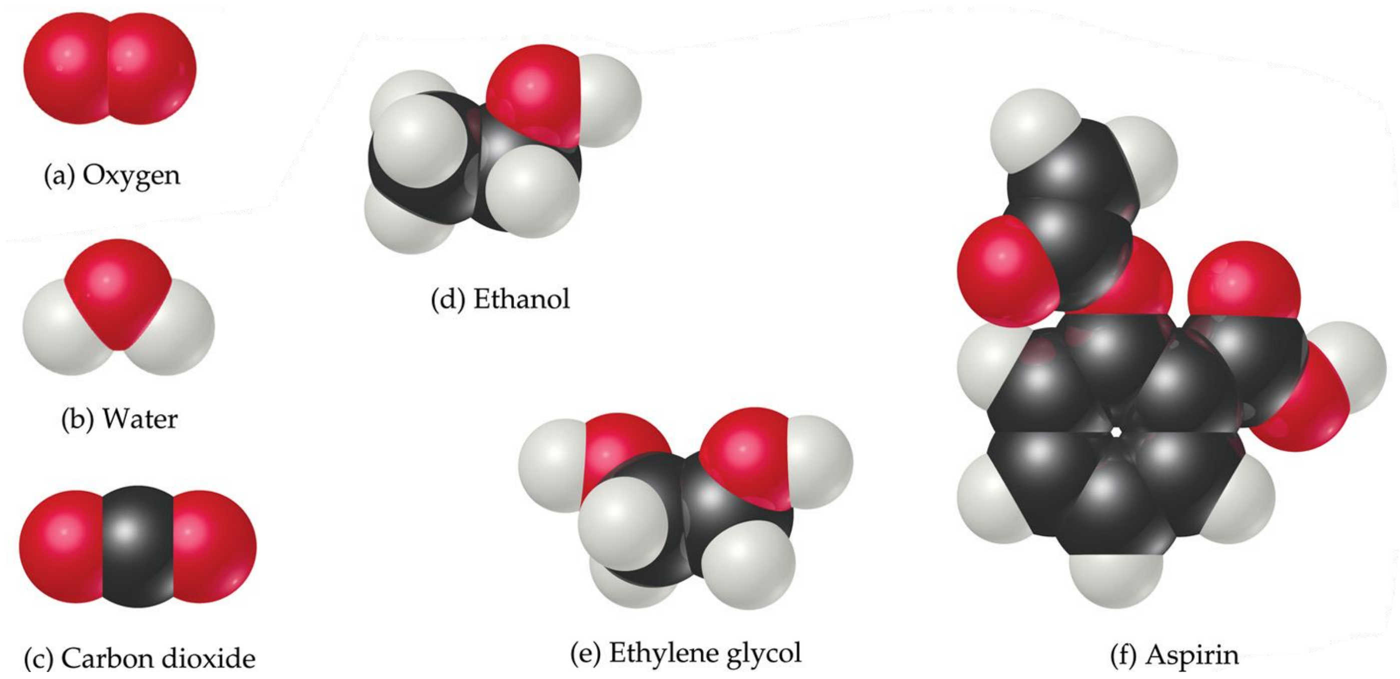
(a) Oxygen

Matter



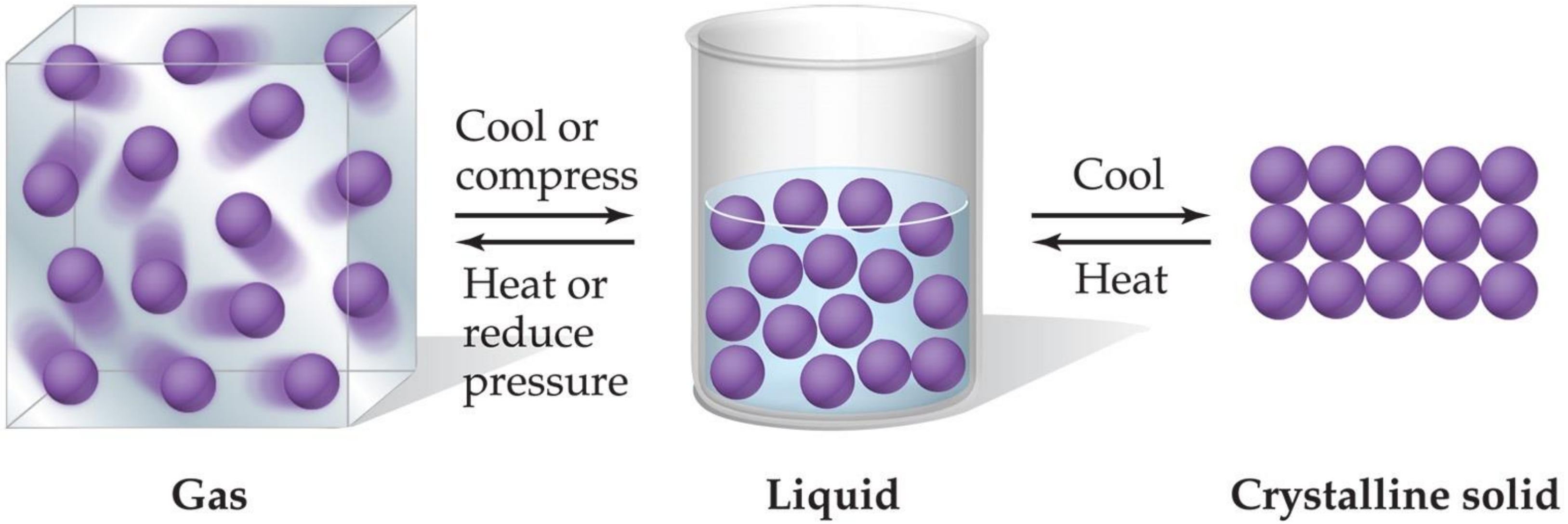
- There are many different kinds of atoms **(elements)**
- Each **element** is made of the same kind of atom.

Matter



- A **compound** is made of two or more different kinds of **elements**.

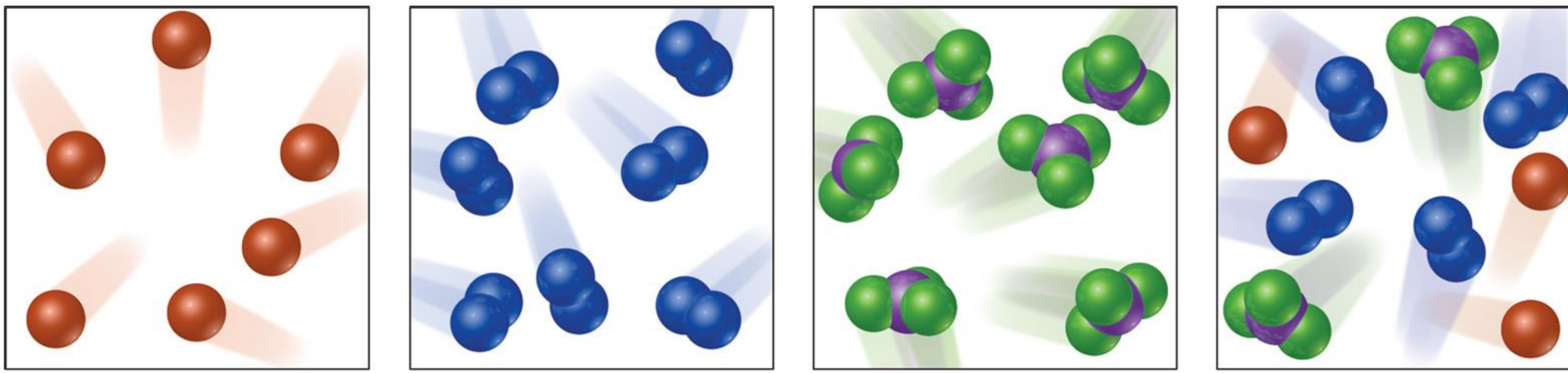
States of Matter



- The same **compound or element can exist**
- **In three different states!**
- **Same stuff, different form.**

Mixtures and Compounds

Element (atoms)	Element (molecules)	Compound (molecules)	Mixture



(a) Atoms of an element

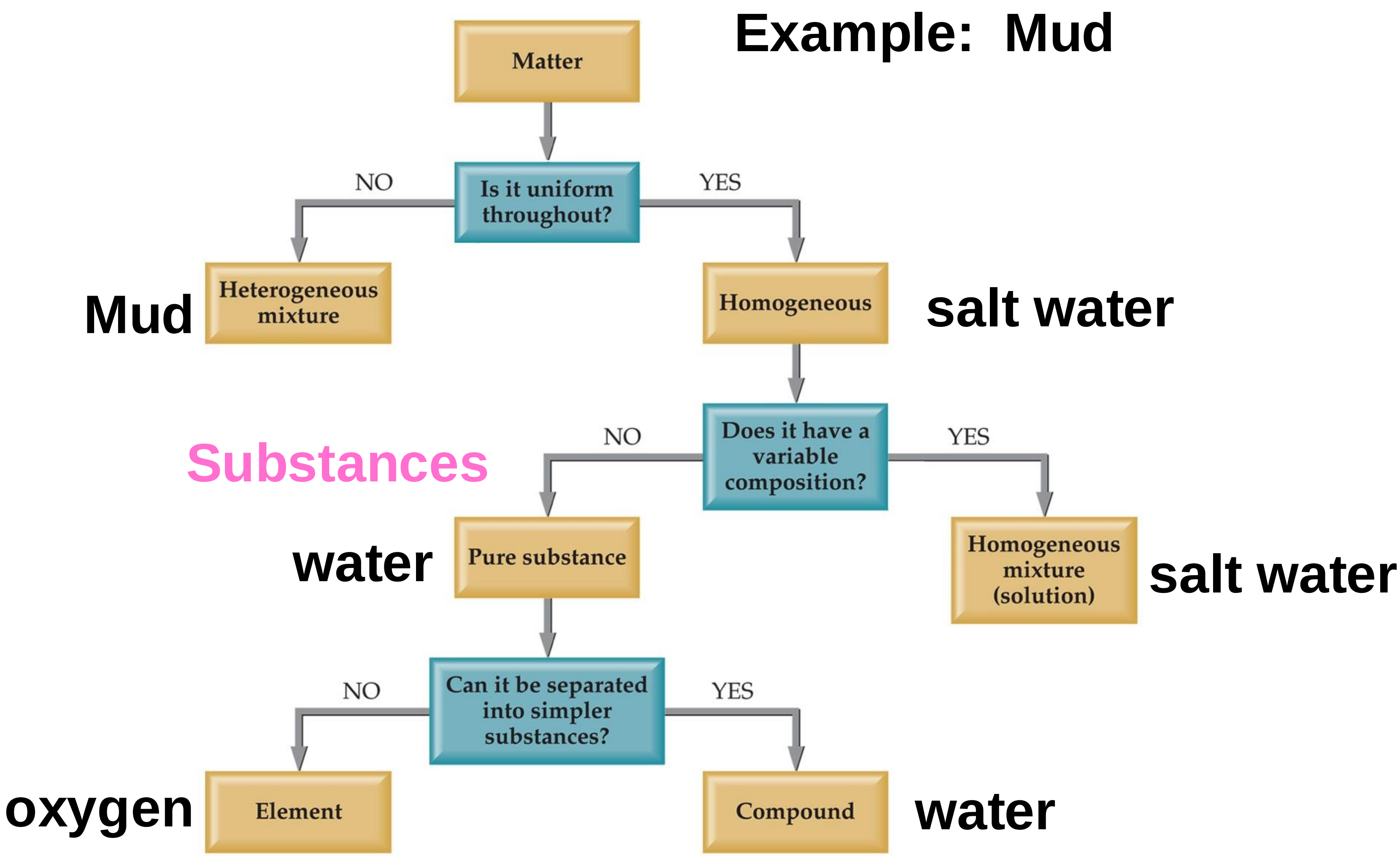
(b) Molecules of an element

(c) Molecules of a compound

(d) Mixture of elements and a compound

He, Ne	N_2, O_2, Cl_2	CO_2, H_2O, NH_3	Mix

Classification of Matter



Properties and Changes of Matter

Properties of Matter

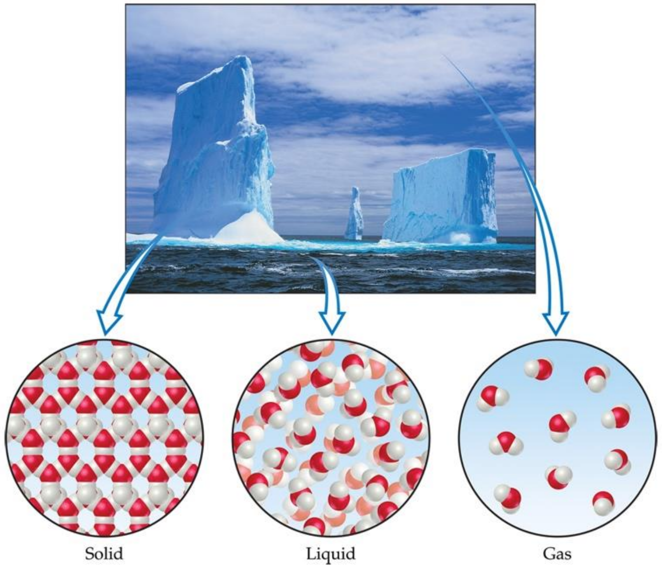
- Physical Properties:
  - □ Must be observed without changing a compound/element into another compound/element.
    - **Boiling point, density, mass, volume, etc.**
- Chemical Properties:
  - □ Can *only* be observed when a compound/element is changed into another compound/element.
    - **Flammability, corrosiveness, reactivity with acid, etc.**

Properties of Matter

- Intensive Properties:
  - □ **Independent** of the **amount** of the matter that is present.
    - **Density, boiling point, color, etc.**
- Extensive Properties:
  - □ **Dependent** upon the amount of the matter present.
    - **Mass, volume, energy, etc.**

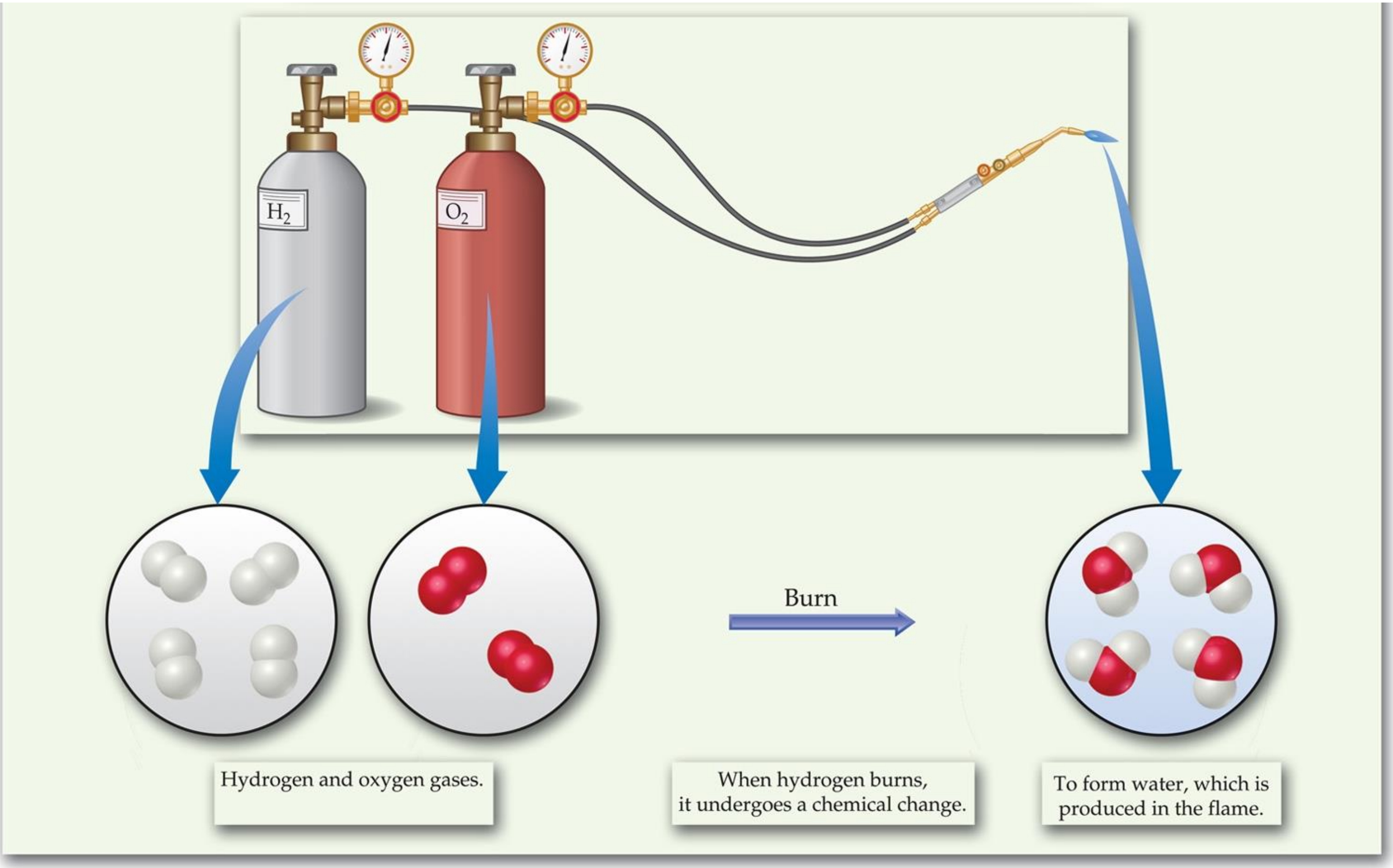
Changes of Matter

- Physical Changes:
  - □ Changes in matter that do not change the composition of a substance.
    - **Changes of state, temperature, volume, etc.**



- Chemical Changes:
  - □ Changes that result in new substances.
    - **Combustion, oxidation, decomposition, etc.**

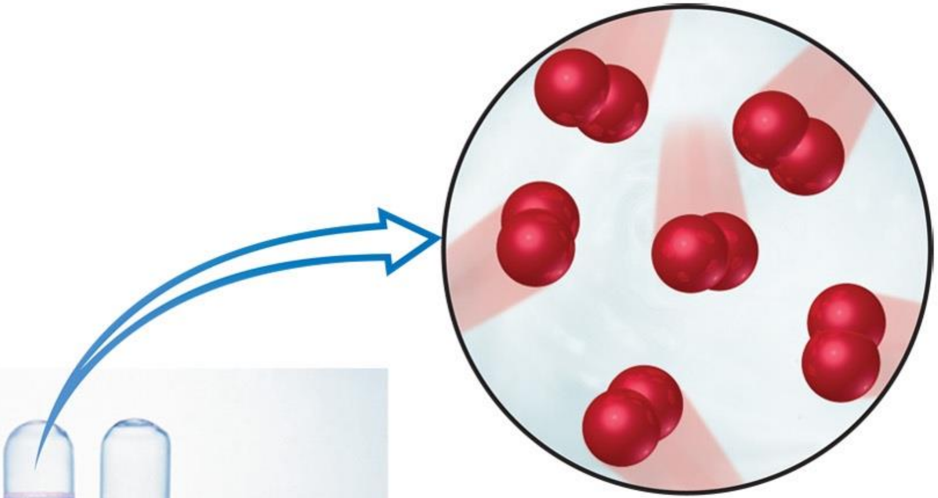
Chemical Reactions

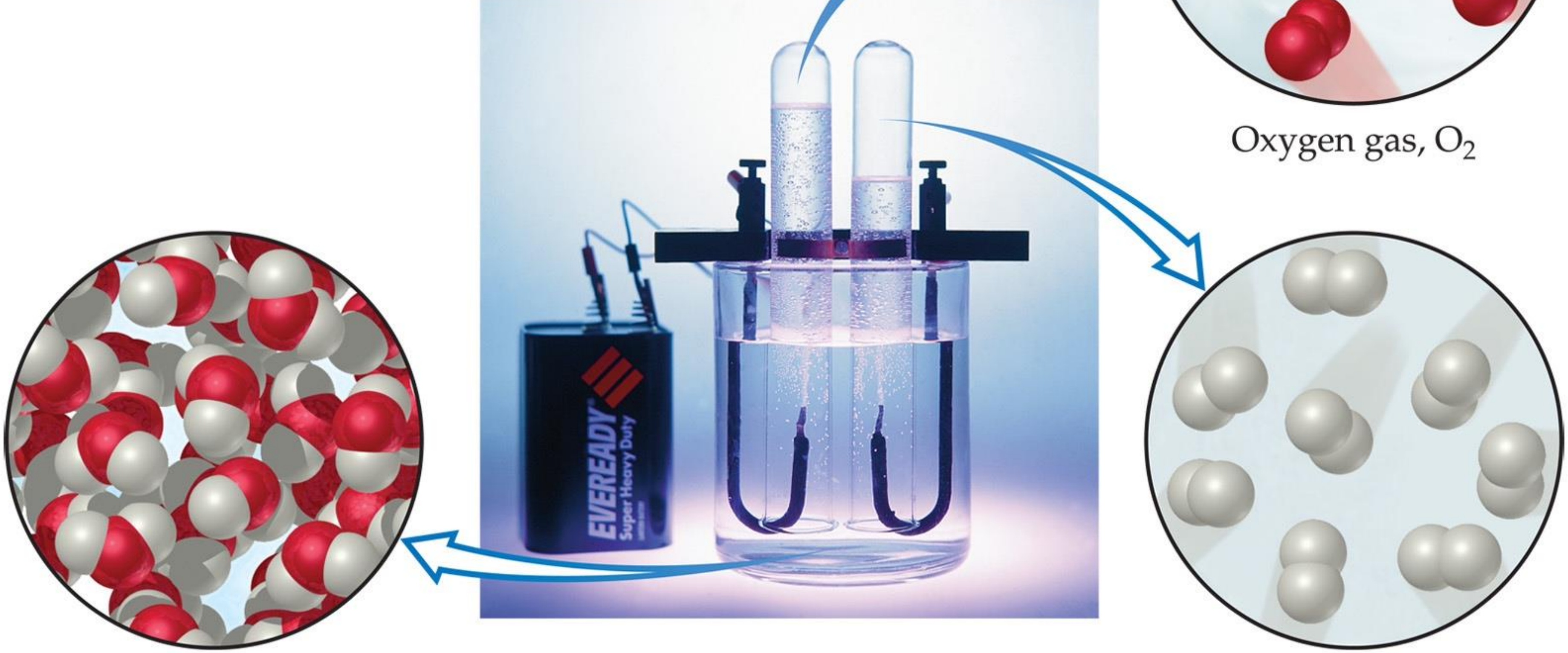


When substances are turned into other substances.

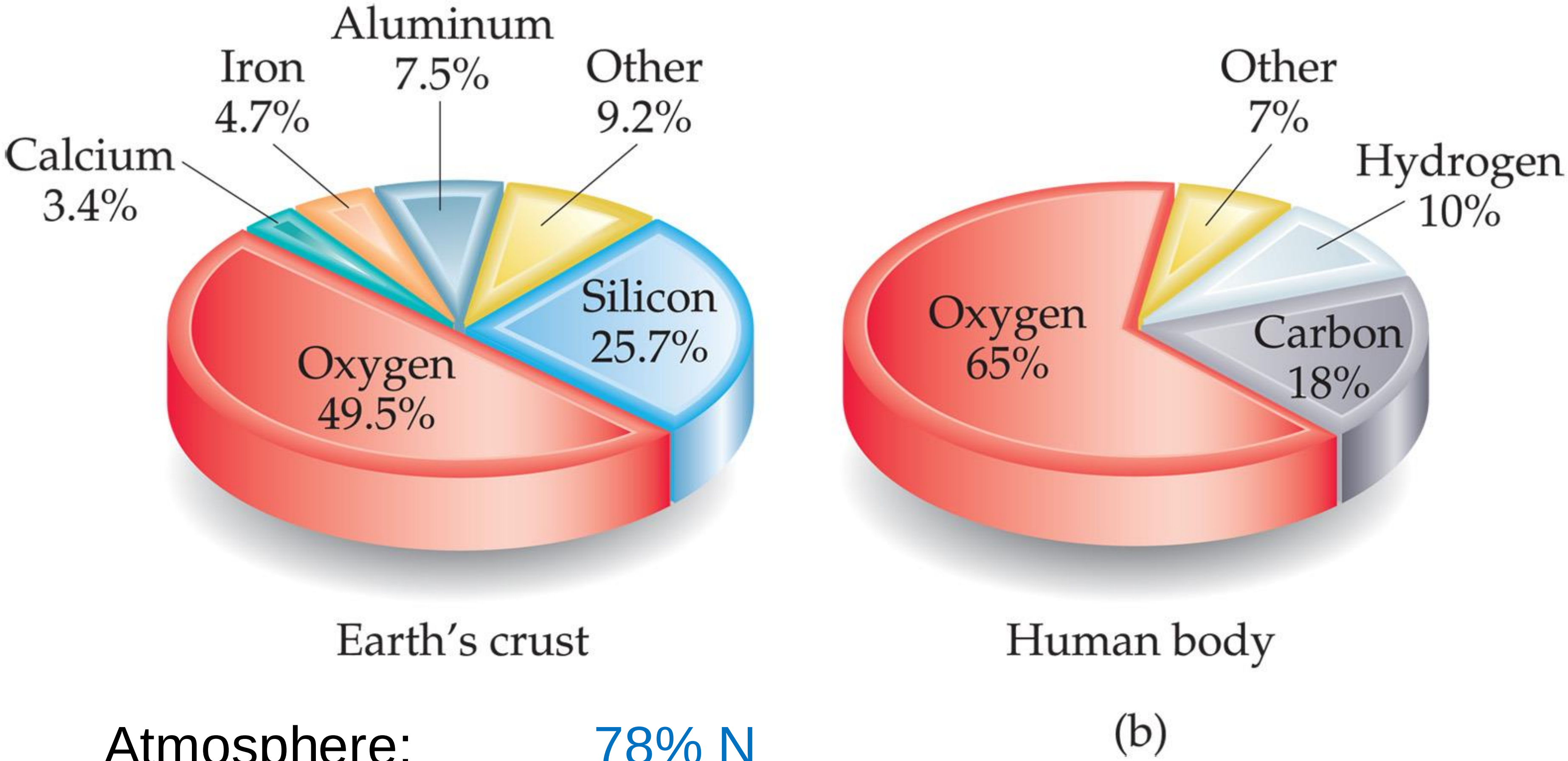
Compounds

Compounds can be broken down into **elements**.





Relative abundance of elements



Prentice Hall, Inc.

Atmosphere:

78% N

21% O

0.93% Ar

0.01% C

TABLE 1.1 The Top Ten Chemicals Produced by the Chemical Industry in 2002[a]

Rank	Chemical	Formula	2002 Production (billions of pounds)	Principal End Uses
1	Sulfuric acid	H_2SO_4	81	Fertilizers, chemical manufacturing
2	Nitrogen	N_2	73	Fertilizers
3	Oxygen	O_2	53	Steel, welding
4	Ethylene	C_2H_4	52	Plastics, antifreeze
5	Lime	CaO	38	Paper, cement, steel
6	Propylene	C_3H_6	32	Plastics
7	Ammonia	NH_3	29	Fertilizers
8	Chlorine	Cl_2	25	Bleaches, plastics, water purification
9	Phosphoric acid	H_3PO_4	24	Fertilizers
10	Sodium hydroxide	$NaOH$	20	Aluminum production, soap

[a]Most data from *Chemical and Engineering News*, July 7, 2003, pp. 53, 56.

Acids

Bases

Pure elements

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Haber Bosch Process
Ammonia synthesis

- $N_2 + 3H_2 \xrightarrow{Fe} 2NH_3$
- Responsible for most of the fertilizer used worldwide
- Uses about 1-2% of world total energy
- Developed by Fritz Haber and Carl Bosch in 1900-1010. Nobel Prize in 1918.
- The trick: finding a **catalyst (Fe)** that works.

Haber Bosch Process

- $N_2 + 3H_2 \rightarrow 2NH_3$
- Nitrates for gunpowder:
- $2NH_3 + 5/2O_2 \rightarrow 2NO + 3H_2O$
- $2NO + O_2 \rightarrow 2NO_2$
- $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$
- Bottom line: once you have ammonia, you can make all kinds of N-containing compounds.
- 80% of the Nitrogen in YOU from Haber/Bosch

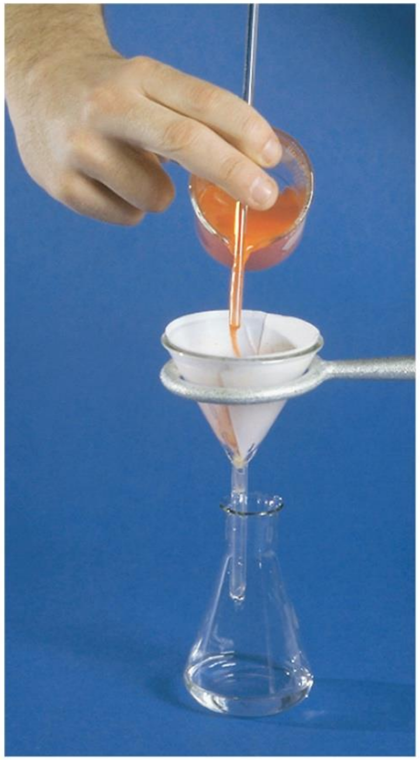
Fritz Haber

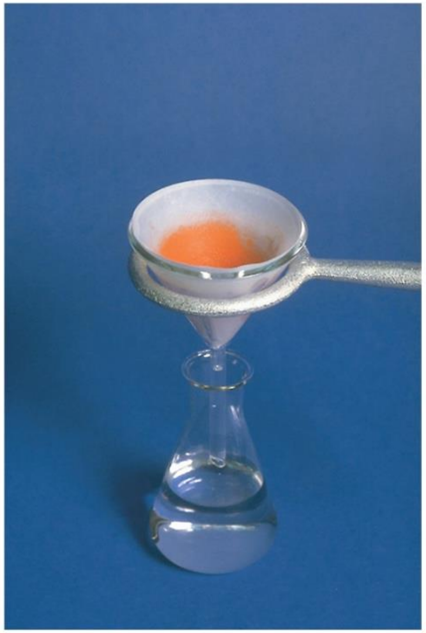
- Jewish
- Converted to Christianity
- Fervently patriotic German
- Developed the first chemical weapons.
- Wife committed suicide in his garden over her opposition to chemical warfare.
- Chlorine led to mustard gas, Zyclon B
- Resigned academic position in 1933 when asked to summarily fire all jews.
- Died in 1934 on his way to Palestine to head the Wiezmann institute.

Ammonia fertilizer runoff Causes Algae blooms

Separation of Mixtures

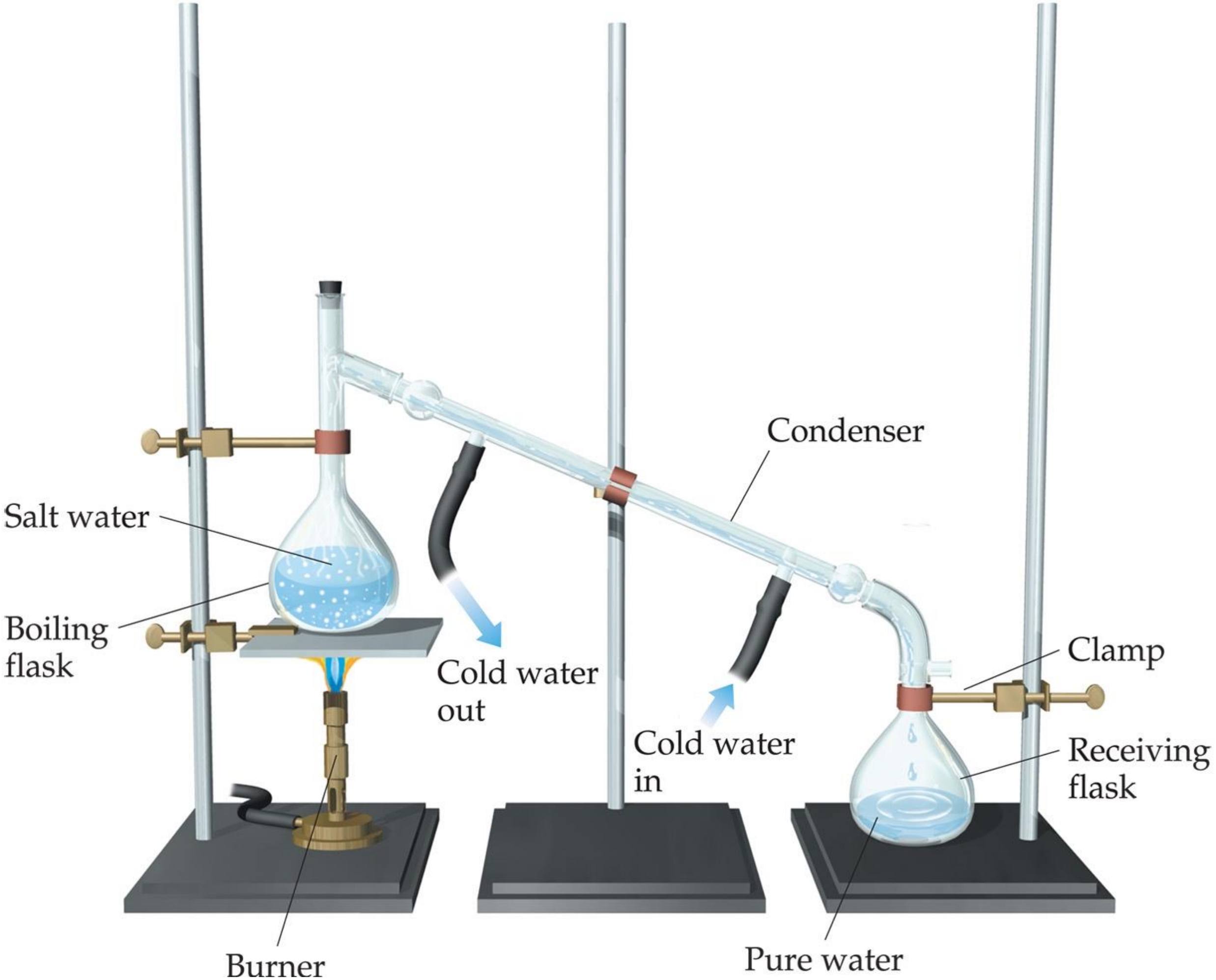
Filtration:





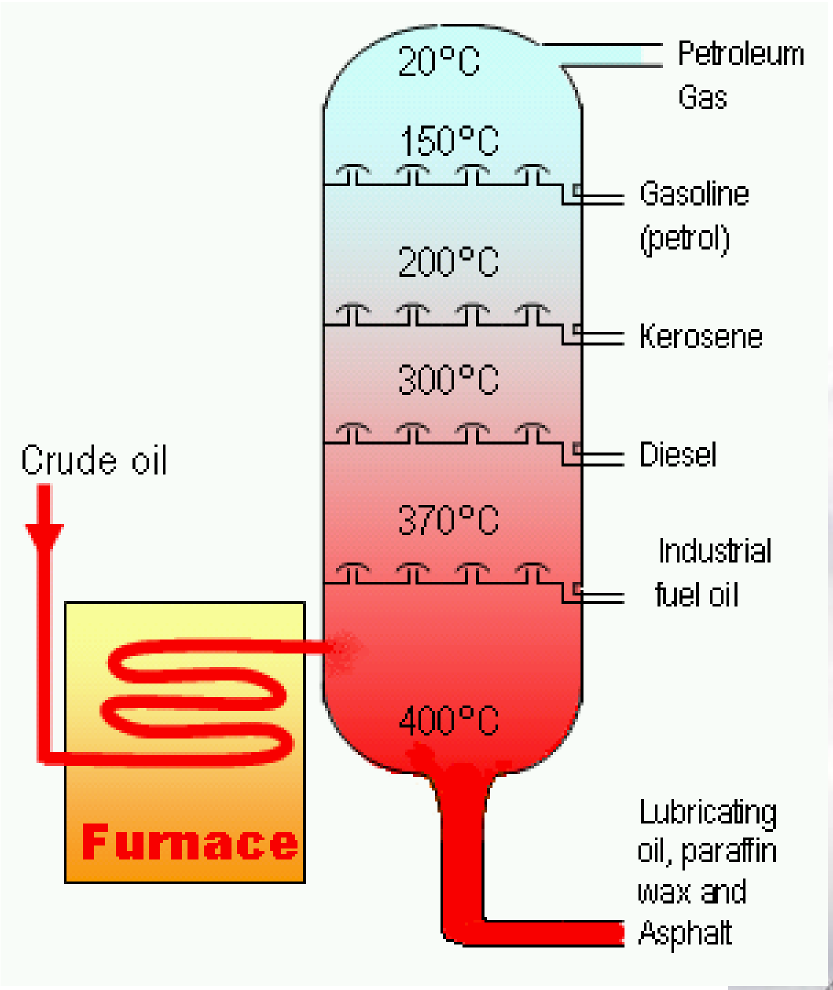
Separates heterogeneous mixture, solid substances from liquids and solutions.

Distillation:



Separates homogeneous mixture of liquids on the basis of differences in boiling point.

Distillation: petroleum refining



Chromatography:

Separates homogeneous mixtures on the basis of differences in solubility in a solvent, or in binding to a solid matrix.

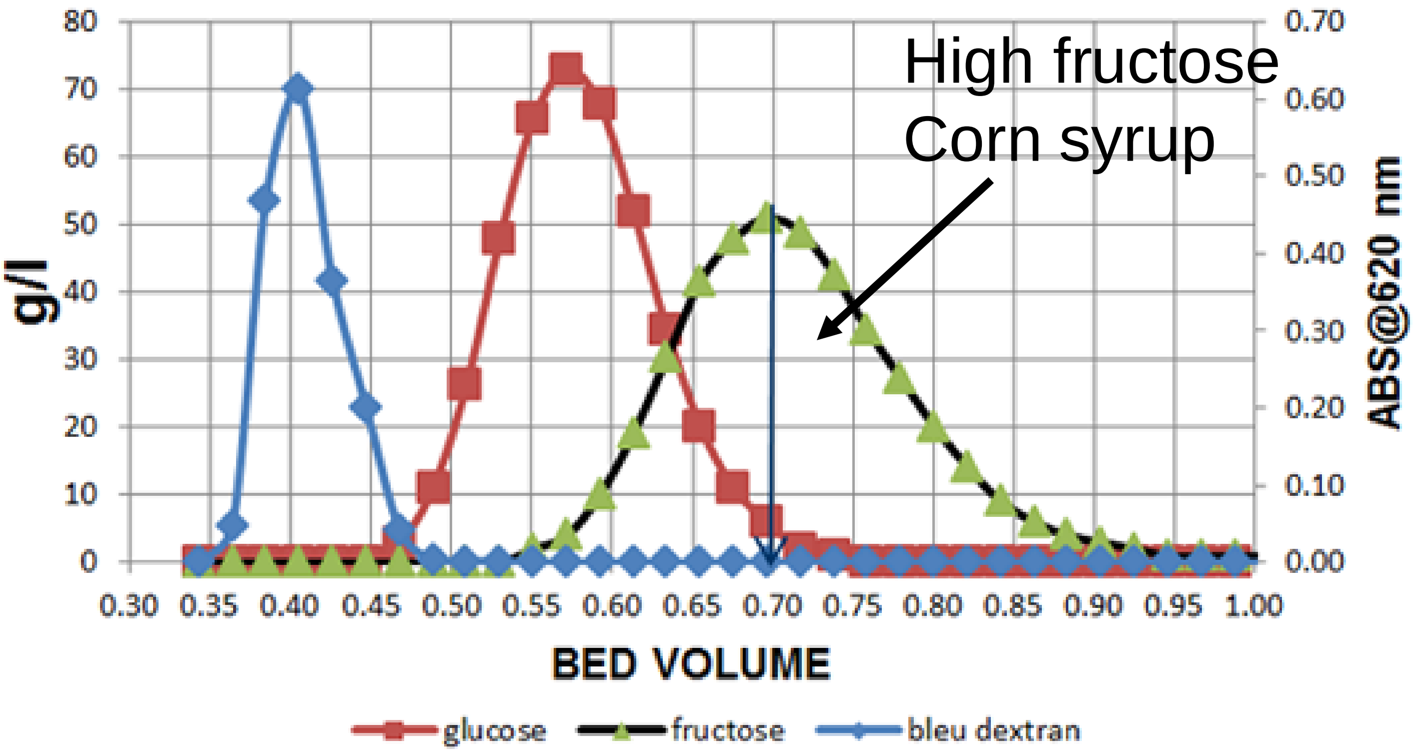
Separation techniques were critical to the development of the basic theories of chemistry.

How do we know there are homogeneous mixtures?

We can separate them.

Chromatography:

Size exclustion chromatography. ”simulated moving bed.” Aqueous phase media.



Units of Measurement

SI Units
Learn! symbols and all!

Physical Quantity	Name of Unit	Abbreviation
Mass	Kilogram	kg
Length	Meter	m
Time	Second	s[a]
Temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Ampere	A
Luminous intensity	Candela	cd

[a] The abbreviation sec is frequently used.

- *Système International d'Unités*
- Uses a different base unit for each quantity
- *Every other unit is defined by these SI units*

Metric System

Prefixes convert the base units into units that are appropriate for the item being measured.

Learn! More important than it looks!!!

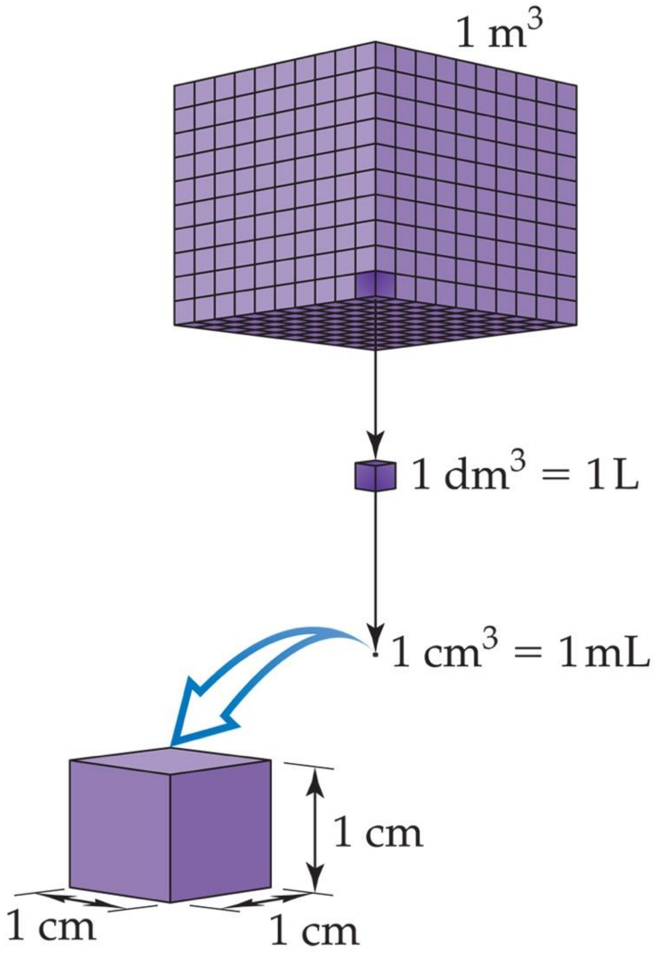
Angstrom: Å 1×10^{-10} m

Prefix	Abbreviation	Meaning	Example
Giga	G	10^{9}	1 gigameter (Gm) $= 1 \times 10^{9}$ m
Mega	M	10^{6}	1 megameter (Mm) $= 1 \times 10^{6}$ m
Kilo	k	10^{3}	1 kilometer (km) $= 1 \times 10^{3}$ m
Deci	d	10^{-1}	1 decimeter (dm) $= 0.1$ m
Centi	c	10^{-2}	1 centimeter (cm) $= 0.01$ m
Milli	m	10^{-3}	1 millimeter (mm) $= 0.001$ m
Micro	μ[a]	10^{-6}	1 micrometer (μm) $= 1 \times 10^{-6}$ m
Nano	n	10^{-9}	1 nanometer (nm) $= 1 \times 10^{-9}$ m
Pico	p	10^{-12}	1 picometer (pm) $= 1 \times 10^{-12}$ m
Femto	f	10^{-15}	1 femtometer (fm) $= 1 \times 10^{-15}$ m

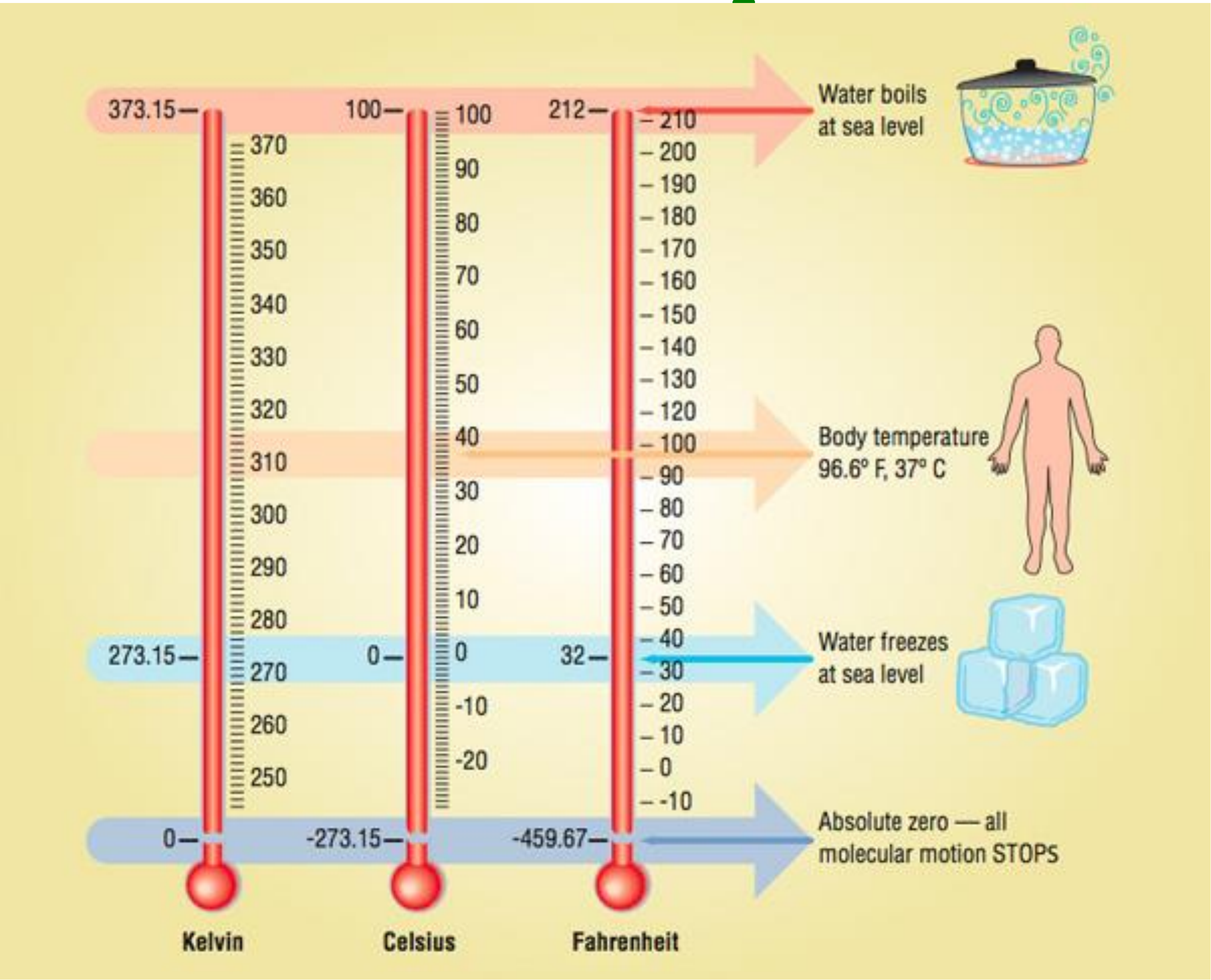
[a]This is the Greek letter mu (pronounced "mew").

Volume

- most common metric units for volume
  - milliliter (mL).
    - a cube 1 cm long on each side.
  - liter (L)
    - a cube 1 dm (10 cm, 0.1 m) long on each side.
    - 1L = 1000 mL



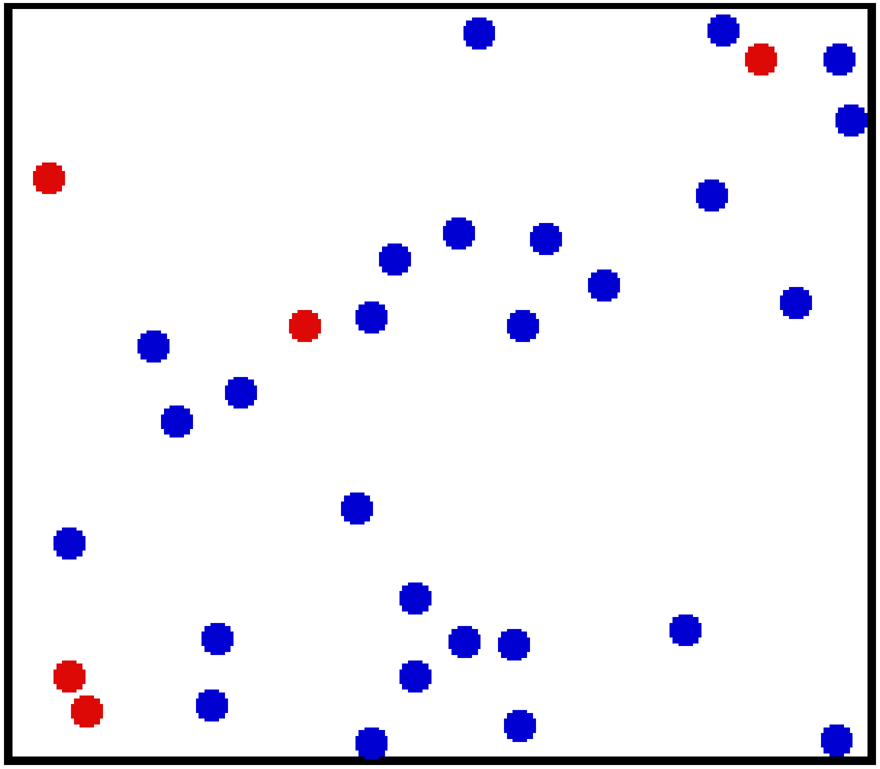
Temperature:



proportional to the average kinetic energy of the particles in a sample.

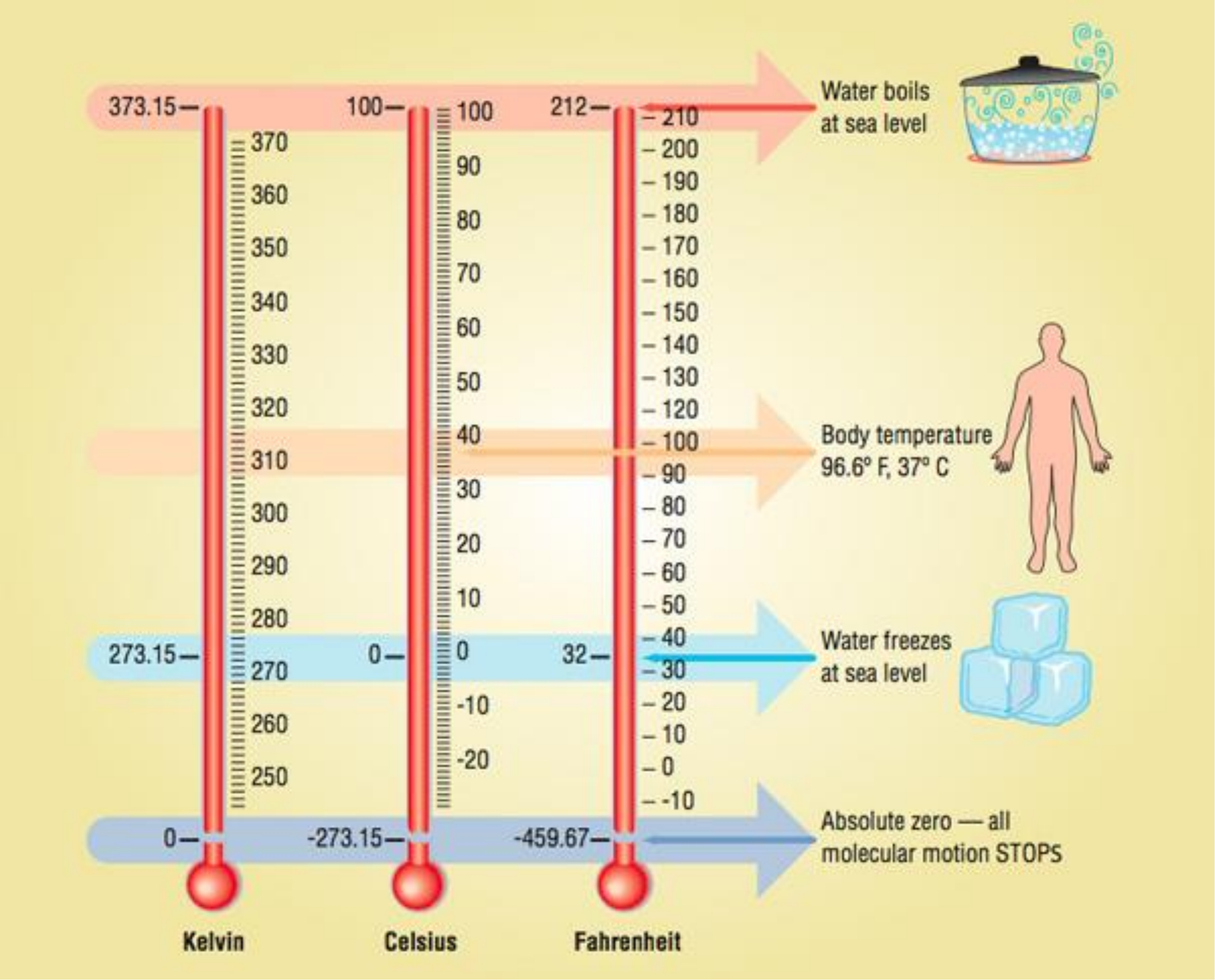
$K.E. = 1/2mv^2$

Kinetic molecular theory.



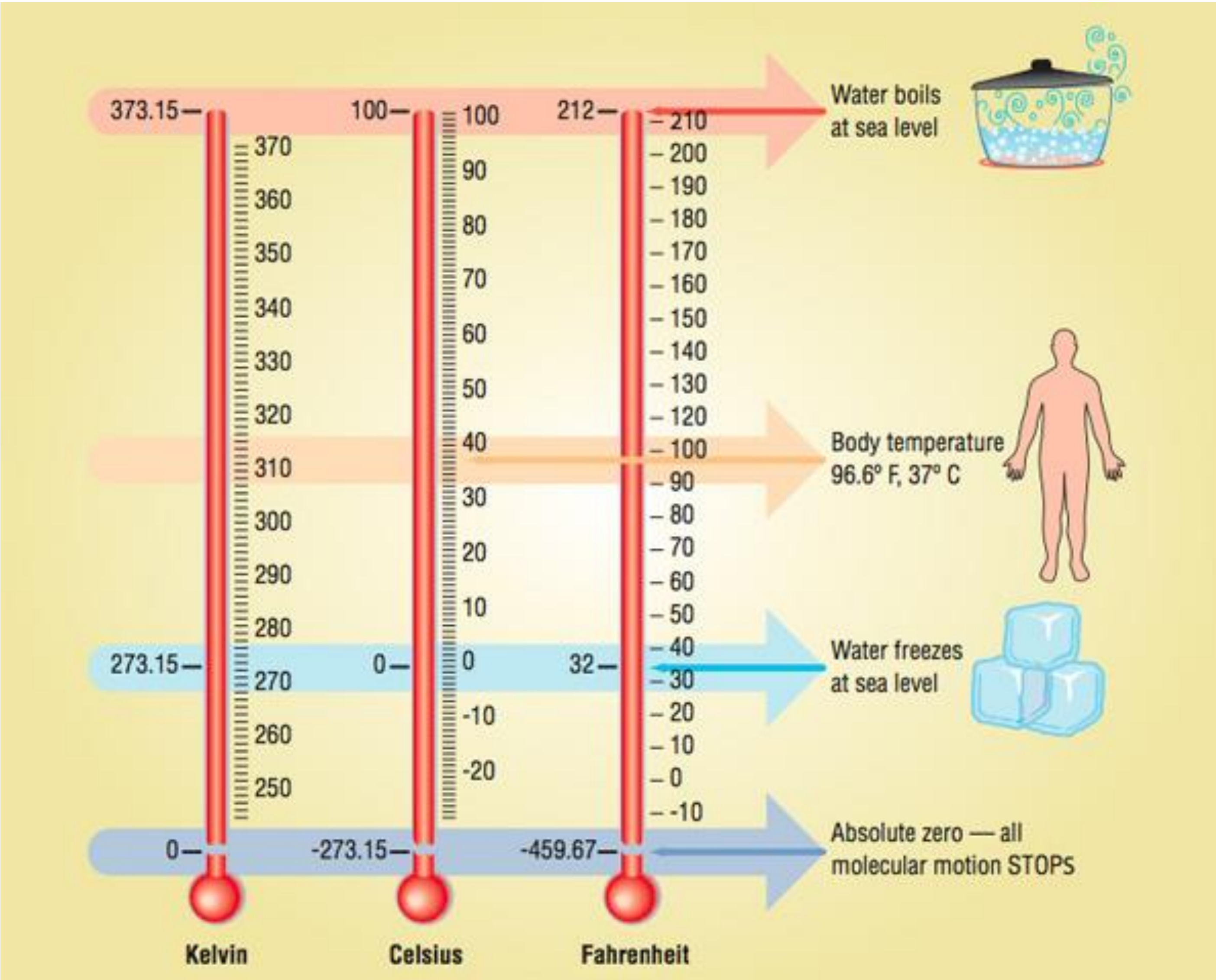
He atoms at 1950 atmospheres. Moving 2 trillion fold (1.0×10^{-12}) slower than they would be at room temperature.

Temperature



- Celsius and Kelvin scales
- The Celsius scale is based on water:
  - 0°C is the freezing point of water.
  - 100°C is the boiling point of water.

Temperature



- Kelvin
  - SI unit of T.

    0 K = 0 K.E.

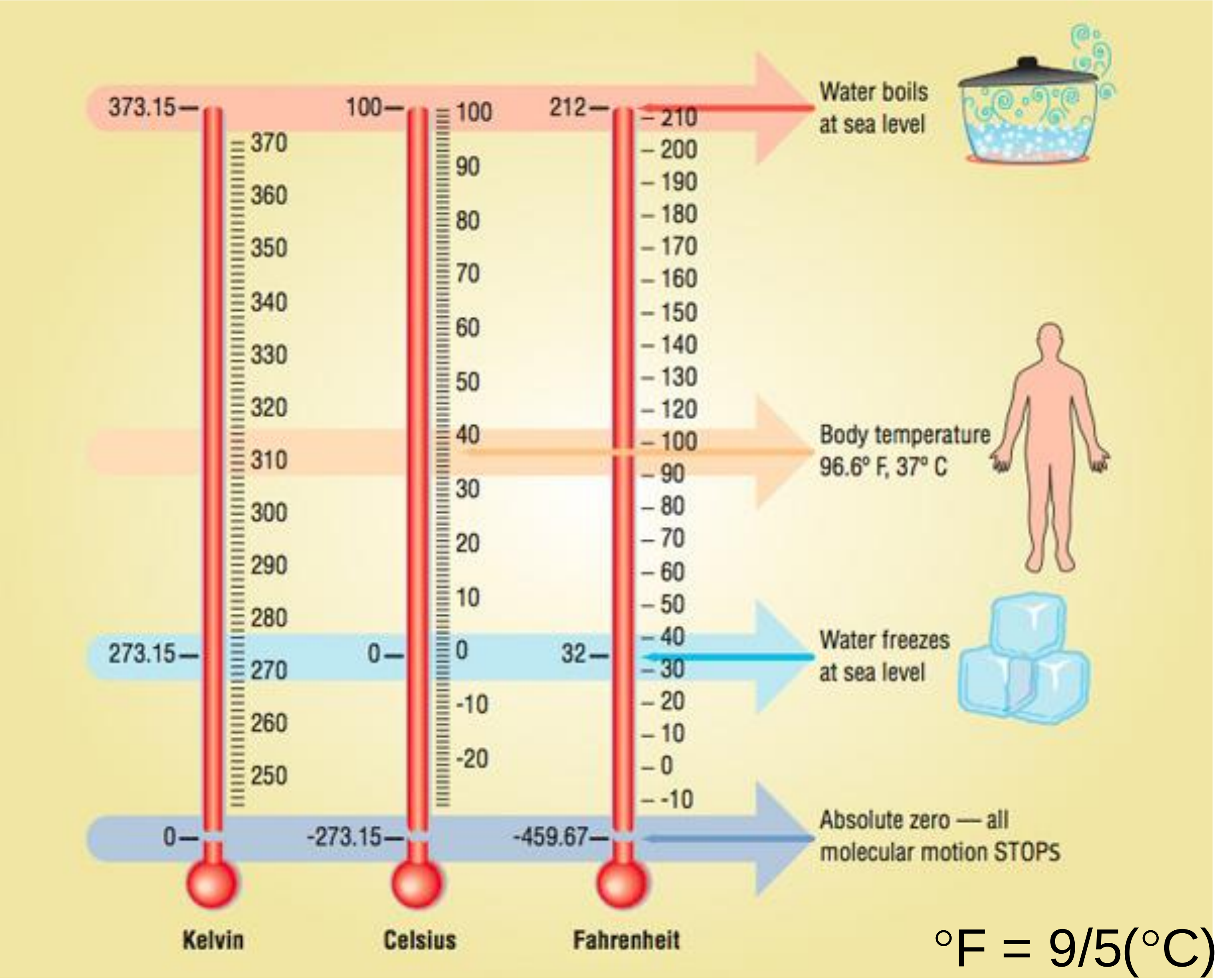
Absolute 0

There are no negative Kelvin.

K = °C + 273.15

There is an absolute, lowest T.

Temperature



The Fahrenheit not used in science

°F = 9/5(°C) + 32

°C = 5/9(°F) − 17.9

Density:

Physical property of a substance

Intensive.

$$d = \frac{m}{V}$$

Density of selected substances

TABLE 1.6 Densities of Some Selected Substances at 25°C

Substance	Density (g/cm^3)
Air	0.001
Balsa wood	0.16
Ethanol	0.79
Water	1.00
Ethylene glycol	1.09
Table sugar	1.59
Table salt	2.16
Iron	7.9
Gold	19.32

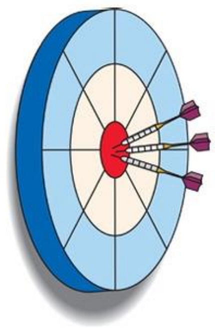
Density depends on two things:

1. How much each atom weighs?
2. How close together they are (how closely packed)

Uncertainty in Measurement

Accuracy versus Precision

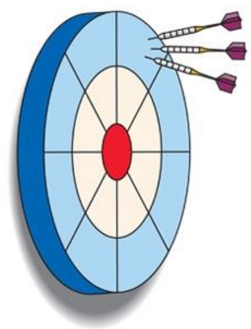
- Accuracy How close a measurement is to the **true** value. (How right you are)



Good accuracy
Good precision

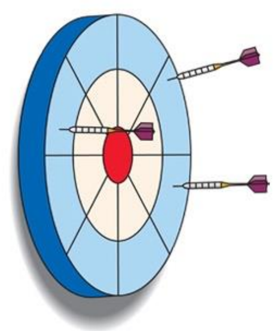
Good accuracy
Good precision

- Precision How close measurements are to **each other.** (Reproducibility). Precise but incorrect data are often the result of systematic errors. For example: *calibration*



Poor accuracy
Good precision

Bad accuracy
Good precision
Your calibration is Off.

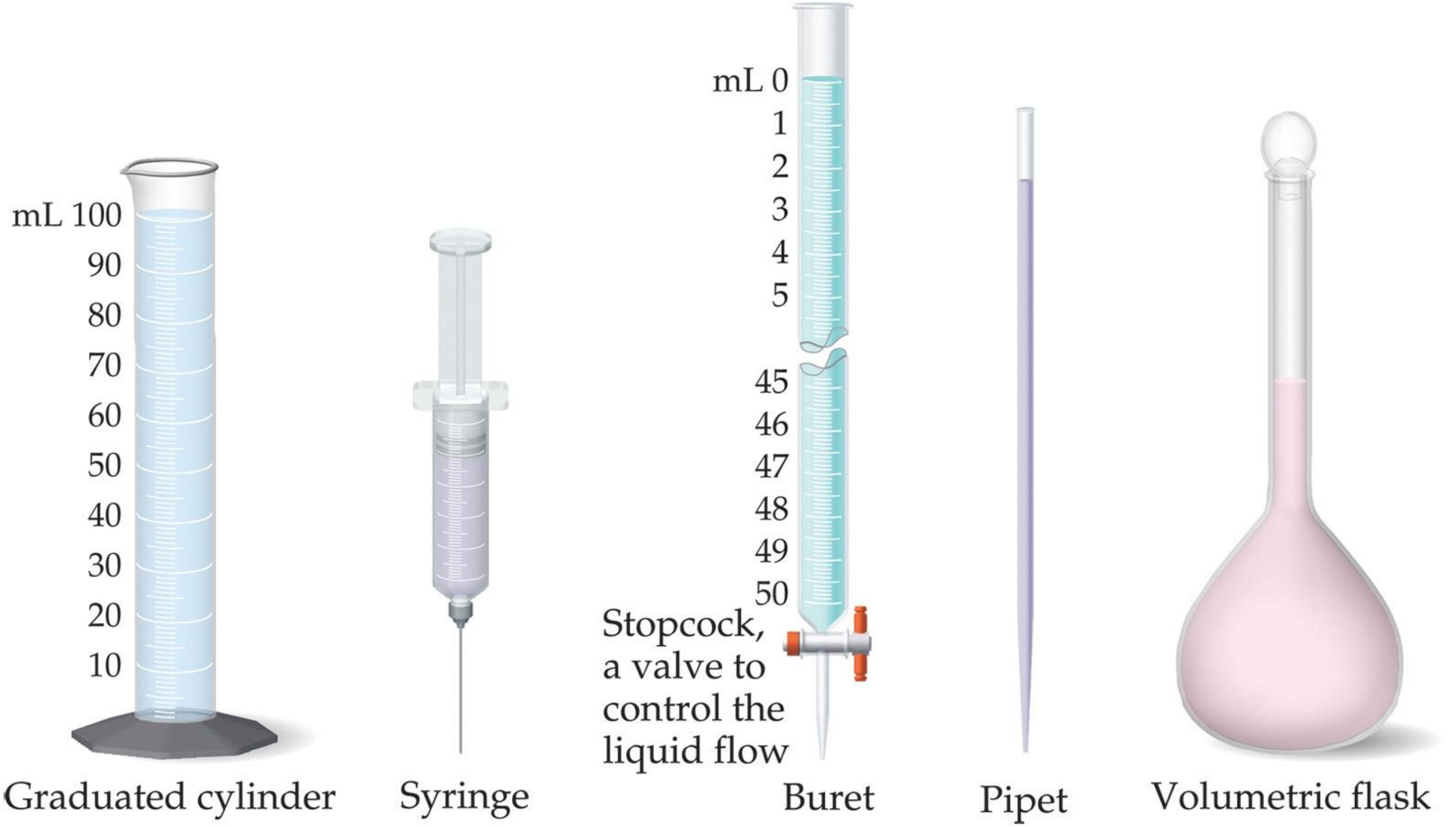


Poor accuracy
Poor precision

Bad accuracy
Bad precision
You can at least tell your answer is wrong

Uncertainty in Measurements

Different measuring devices have different uses and different degrees of accuracy/precision.



No measurement is perfect.

Always has some degree of error.

Exact versus Inexact numbers

Exact	Inexact
1000 g/kg	ruler measure
2.54 cm/in	Temp. reading
12/dozen	volume or mass
any conversion	etc. **Things you**
Factor	**measured**

Exact numbers are defined

Inexact numbers are measured

Example

- There are 12 eggs in a dozen
- Each egg weighs about 50.5 g
- How much does a dozen eggs weigh?
- How many sig. figs in your answer?

Example

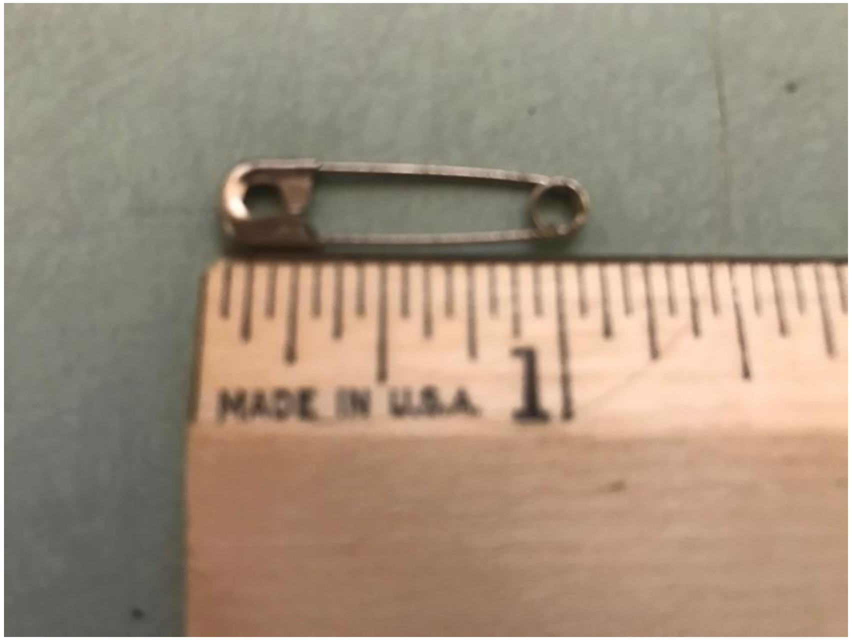
- There are 12 eggs in a dozen
- Each egg weighs about 50.5 g
- How much does a dozen eggs weigh?
- How many sig. figs in your answer?

$$\frac{50.5g}{1egg}\left(\frac{12egg}{1dozen}\right) = 606 g/dozen$$

Significant Figures

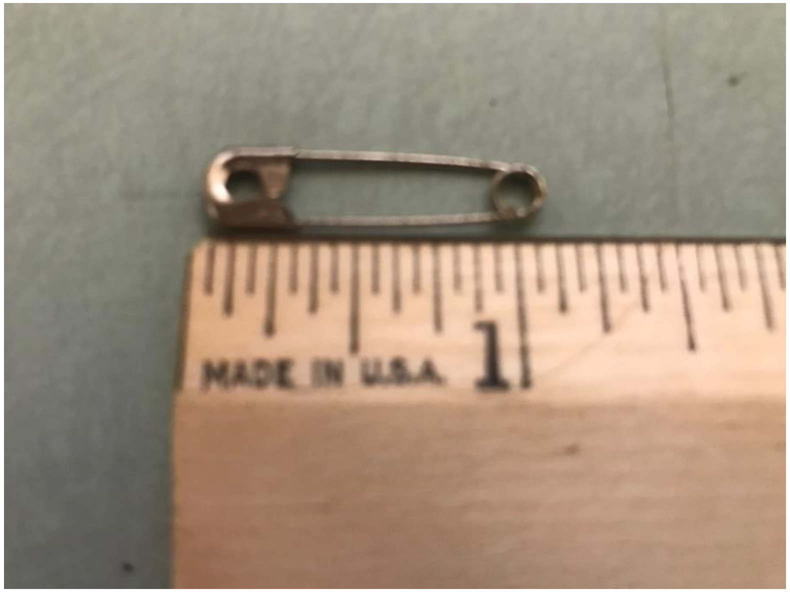
- The term significant figures refers to digits *that were measured.*
- When rounding calculated numbers, we pay attention to *significant figures* so we do not overstate or understate the precision of our answers.
- Otherwise we are *lying.*

Significant Figures



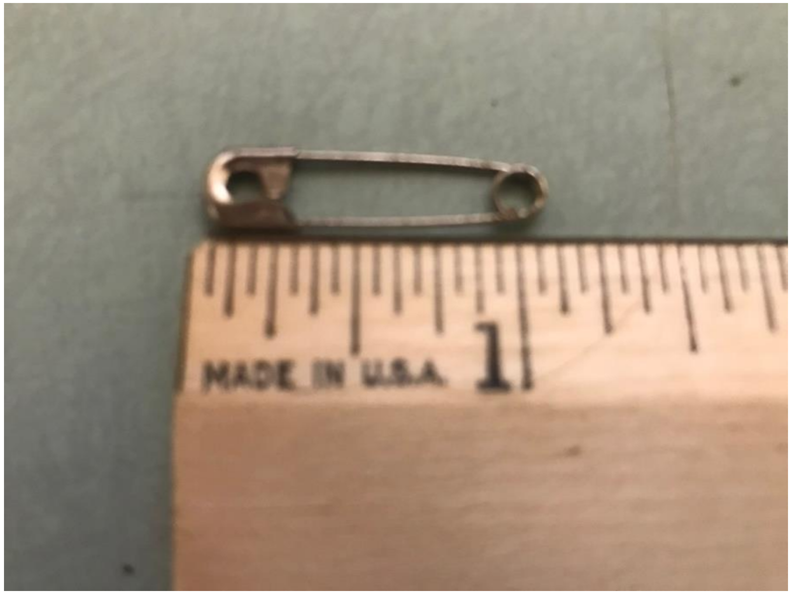
- The term significant figures refers to digits *that were measured*.
- What is the length of the safety pin?

Significant Figures



- The term significant figures refers to digits *that were measured*.
- What is the length of the safety pin?
- 1 and 1/16 inches or 1.0625 inches
- How many of these digits are significant?

Significant Figures



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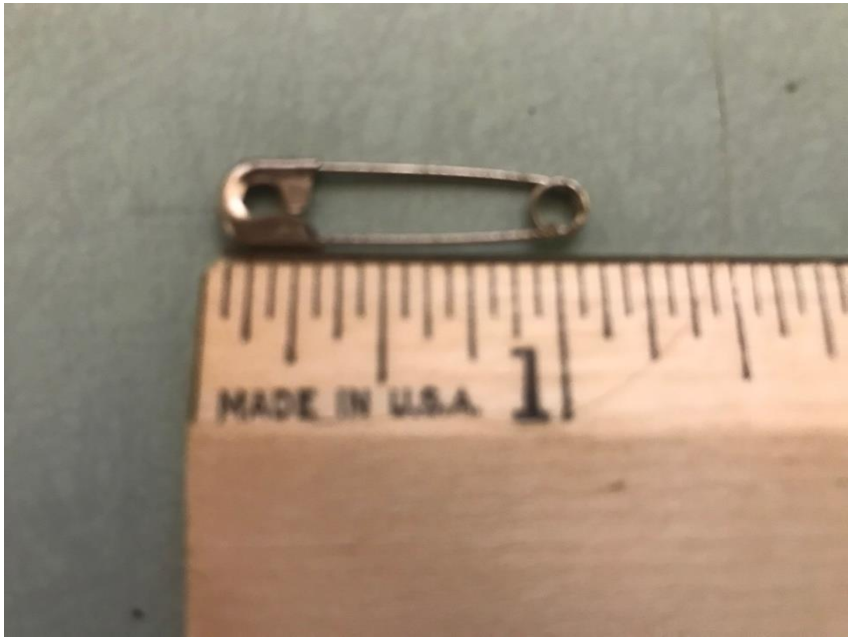
Significant Figures



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- 1 and 1/16 inches or 1.0625 inches
- How many of these digits are significant? **At most 3.**
- **Length = 1.06 in.**

- So how do we communicate this ***essential*** information when we write numbers down?

Significant Figures

1. All nonzero digits are significant. (sig figs in **red**)

   423.444

2. Zeroes between two significant figures are themselves significant.

   42,300045   42,340.0025

3. Zeroes at the beginning of a number are never significant.

   00042345.0 0.00048

4. Zeroes at the end of a number are significant ***only*** if a decimal point is written in the number.

   423,000 versus: 423,000. or: 423,000.000

Significant Figures
What about calculations?

- When addition or subtraction is performed, answers are rounded to the least significant decimal place.

```
  24.245
+22.33488
  46.57988 = 46.580
```

- When multiplication or division is performed, answers are rounded to the number of digits that corresponds to the *least* number of significant figures in any of the numbers used in the calculation.

```
 35.8750     (6 sig figs)
X40.006800  (8 sig figs
1435.24395 = 1435.24  (6 sig figs)
```

- **This is the way that errors are properly propagated through a calculation**

Dimensional analysis

What do virtually all problems in chemistry have in common?

Dimensional analysis

Convert centimeters to feet: 1 cm = ? feet

Know: 2.54 cm = 1 in, 12 in = 1 foot.

$$\frac{1\,in}{2.54\,cm}\left(\frac{1\,ft}{12\,in}\right) = 0.0328\,\frac{ft}{cm}$$

Dimensional Analysis

- What do I need on top?
- What do I need on the bottom?
- What do I know?
- How do I get there?
- Note: You will always be given the conversion factors you need, *you don't have to memorize them.*

Dimensional Analysis

- Remember, you can write any conversion factor 2 ways:
- Example: 2.54 cm = 1 in
- 1 in/2.54 cm
- 2.54 cm/1 in

Dimensional analysis, examples

The speed of light is 2.998×10^{10} cm/s. What is it in km/hr?

Know: 1 km =1000m, 1m=100cm 60 min =1 hr, 60 sec =1 min

What do I need on top? *kilometers*

What do I need on the bottom? *hours*

Dimensional analysis, examples

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What do I need on the bottom? *hours*

$$2.998x10^{10}\frac{cm}{s}\left(\frac{1m}{100cm}\right)\left(\frac{1km}{1000m}\right)\left(\frac{60\sec}{1\min}\right)\left(\frac{60\min}{1hr}\right)=1.089x10^{9}\,km/hr$$

Dimensional analysis, examples

The Vehicle Assembly Building (VAB) at the Kennedy Space Center has a volume of: 3,666,500m^3. What is the volume in liters?

Know: 1 L = 1 dm^3, 1dm = 0.1 m

What do I need on top? *Liters*

What do I need on the bottom? *building*

$$3,666,500\left(\frac{m^3}{building}\right)\left(\frac{dm}{0.1m}\right)^3\left(\frac{1L}{1dm^3}\right)=3.6665x10^9\ \frac{L}{building}$$

Dimensional analysis, examples

A patient suffering from high cholesterol has 232 mg cholesterol per 100.0 mL of blood. How many grams of cholesterol total in the blood of the patient, assuming a blood volume of 5.2 L?

Know: 1 L = 1000 mL, 1g = 1000mg,

5.2 L = total volume of patient's blood

What do I need on top? *Grams of cholesterol in patient.*

What do I need on the bottom? *patient*

$$232\frac{mg}{100.0\,mL}\left(\frac{1g}{1000\,mg}\right)\left(\frac{1000\,mL}{1\,L}\right)\left(\frac{5.2\,L}{patient}\right)=12.\frac{g}{patient}$$

Problem

- Consider a piece of gold jewelry that weighs 9.35 g and has a volume of 0.695 mL . The jewelry contains only gold and silver, which have densities of 19.3 and 10.5 , respectively. If the total volume of the jewelry is the sum of the volumes of the gold and silver that it contains, calculate the percentage of gold (by mass) in the jewelry.

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Problem

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M_{Ag} + M_{Au} = 9.356 g

M_{Ag} = 9.356 g - M_{Au}

V_{Ag} + V_{Au} = 0.695 mL

V = $\frac{M}{D}$

$\frac{M_{Au}}{D_{Au}} + \frac{M_{Ag}}{D_{Ag}}$ = 0.695 mL

$\frac{M_{Au}}{D_{Au}} + \frac{9.356g - M_{Au}}{D_{Ag}}$ = 0.695 mL

$$M_{Au}(\frac{1}{D_{Au}} - \frac{1}{D_{Ag}}) = 0.695\ mL - \frac{9.356\ g\ mL)}{D_{Ag}}$$

$$M_{Au} = \frac{D_{Ag}(0.695\ mL) - 9.356\ g}{D_{Ag}(\frac{1}{D_{Au}} - \frac{1}{D_{Ag}})} = \frac{10.5 gmL^{-1}(0.695\ mL) - 9.356\ g}{10.5(.05181 - .09524)} =$$

4.5 g

4.5/9.356= .48. 48%

Facts and theories

*Fact: on June 30, 1908 in Tunguska, Siberia, an explosion equivalent to about 15 million tons of TNT occurred.

* **Hypothesis** is that a comet or meteor collided with the Earth.

http://en.wikipedia.org/wiki/Tunguska_event

Testing: look for elements and substances characteristic of extraterrestrial objects, elements not found in the area. Such elements (Nickel, Iridium) were found.

However, there is no crator.
Theory: Meteor exploded above the ground.